

Seasonal variations in species diversity, dry matter and net primary productivity of herb layer of *Quercus leucotrichophora*-*Pinus roxburghii* mixed forest in Kumaun Himalaya, India

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Abstract: Plant biomass, species diversity and net primary productivity are presented for herb layer of banj oak (*Quercus leucotrichophora* A. Camus)-chir pine (*Pinus roxburghii* Sarg.) mixed forest in Kumaun, central Himalaya, India. The species diversity declined from a maximum (3.56) in September to a minimum (2.11) in December. The monthly live shoots biomass exhibited a single peak growth pattern with highest live shoot biomass of 185 g·m⁻² in August. The seasonal pattern showed that the maximum above-ground production (131 g·m⁻²) occurred during the rainy season and the minimum (1 g·m⁻²) during winter season. The below-ground production was maximum during winter season (84 g·m⁻²) and minimum during summer season (34 g·m⁻²). The annual net shoot production was 171 g·m⁻² and total below-ground production was 165 g·m⁻². Of the total input 61% was channeled to above-ground parts and 39% to below-ground parts. Transfer of live shoots to dead shoots compartments and that of dead shoots to litter compartments was 61% and 66%, respectively. The total dry matter disappearance was 61% of the total input within annual cycle. The herb layer showed a net accumulation of organic matter, indicating the seral nature of the community.

Keywords: above ground production; below ground production; litter mass; phytomass; turnover rate

Introduction

All the land use categories of the Central Himalaya viz., close-canopies forest, forest with partial tree cutting and clear felled forest occupied by grasses or converted into scrubs and crop fields and natural alpine grass lands (between 3,000–4,000 m elevation or more) are subjected to free grazing of livestock. Within the Himalaya (below 3,000 m elevation) the relationship between man and forests through his livestock has been very intimate since time immemorial. The grasslands below 3,000 m elevation have resulted from extensive clearing of forests due to cultivation, burning and heavy grazing pressure. Such grasslands have developed around human settlements and their areas are increasing with receding forest boundaries (Joshi 1991).

All the grasslands and the forest floor vegetation under different forests are extensively used as grazing grounds with little regulation often beyond their carrying capacities (Singh et al. 1988). In spite of close linkages between man and forests through livestock little information is available on the structure and functioning of forested grazing lands in lower elevation ranges of Himalayan (Saxena and Singh 1980; Singh 1991). Herbaceous layer is an important component of terrestrial ecosystem and plays an important role in primary production and turnover (Das et al 2008). An understanding of seasonal changes in species diversity, biomass dynamics and net primary productivity of forested grazingland is not only useful for assessing the seasonal forage availability but also important to assess the carrying capacity of the grazing lands of lower elevations of Himalaya and their management.

The present study was attempted to describe species diversity, dry matter dynamics and net primary productivity of herb layer of banj-oak (*Quercus leucotrichophora* A. Camus) -chir pine (*Pinus roxburghii* Sarg.) mixed forest Kumaun Himalaya.

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Materials and methods

Study site

The study was conducted at a site located between 1,700–2,000 m elevations in Kumaun Himalaya, India (29°27′–29°29′N and 79°23′–79°25′ E). The soil of the study area (0–30 cm depth) was residual, shallow and sandy in texture (sand 57%, silt 28% and clay 15%). Water holding capacity was 54% and bulk density 0.89 g·cm⁻³. The climate of the area is temperate monsoon. About 75% of the rain occurs from mid-June to mid-September. The mean daily maximum temperature varies from 12.5°C to 23.8°C (May), and the mean minimum from 7.2°C (December) to 17.0°C (June). Depending on climatic variations, the year is divisible into (1) a dry and warm summer season (March to May), (2) a wet and warm rainy season (June to September), and (3) a dry and cold winter season (October to February).

A forest of an area of 1 ha was secured for the study. For biomass estimation, the herbaceous component was divided into the following compartments: live shoots, dead shoots, litter and below ground live component. Then live shoot compartment was separated species-wise. Various species recorded were categorized into growth forms viz., (1) tall forms (> 30 cm tall plants with scattered leaves all along the erect stems), (2) short forbs (≤ 30 cm tall plants with leaves arranged in short umbrella-like structures with or without arching stems), (3) grasses and (iv) cushion and spreading forbs including rosette forming and prostrate forms.

The shoot biomass was harvested as close to the ground as possible from ten randomly selected 1 m × 1 m plots at 30-day intervals and no plot was harvested more than once. Litter was collected from each harvested plot and was washed through flotation. The samples were placed in perforated paper bags, brought to the laboratory, oven-dried at 80°C till constant weight and weighed. The below-ground plant material was collected from one monolith (25 cm × 25 cm × 30 cm) from each harvested plot, subsequent to above-ground components. The monoliths were brought to the laboratory and washed with a fine jet of water using 2 mm and 0.5 mm mesh screens. The samples were dried at 80°C to constant weight and weighed. The importance value index (IVI) for all the species was determined as the sum of the relative frequency, relative density and relative dominance (Curtis 1959). Species diversity (*H*) was calculated on the basis of live shoots biomass as described by Smith (1980), viz.

$$H = 3.322 [\log_{10} N - (1/N \sum N_i \log_{10} N_i)] \quad (1)$$

where *N* is the total shoot biomass and *N_i* is the biomass of species *i*, both in g·m⁻².

Net above-ground primary production (ANP) was determined as sum of positive changes in above-ground biomass plus mortality (Ram et al. 1989; Singh and Yadava 1994). Dry matter which had been produced and disappeared within a sampling interval could not be estimated in the presented study. Thus, the production estimated was considered as minimum. The below-ground

net production (BNP) was estimated by summation of the positive changes in the below-ground biomass (Singh and Yadava 1974). Difficulties and errors involved in the estimation of BNP are discussed by several authors (Schuuroman and Goedewaagen 1964; Head 1970; Sims and Singh 1978b).

The rate of below-ground biomass was calculated using the formula as proposed by Dahlman and Kucera (1965):

$$\text{Turnover} = \frac{BNP}{MBGB} \quad (2)$$

where *BNP* is the below-ground net production, *MBGB* is the maximum below-ground biomass.

Net accumulation and disappearance rates for dry matter were calculated by the methods of Singh and Yadava (1971), Sims and Singh (1978c) and Ram et al. (1989) as follows:

Transfer of live shoots to dead shoots was calculated by summation of the positive change in dead shoots on successive sampling date;

Transfer of dead shoots to litter was calculated by summation of negative changes in the dead shoots;

Disappearance of litter (*LD*) was calculated as:

LD = (initial amount of litter + litter production) – (amount of litter at the end);

Disappearance of below-ground biomass (*BD*):

BD = (initial below-ground biomass) + (*BNP*) – (final below ground biomass);

Total disappearance (*TD*):

TD = *LD* + *BD*

Statistical analyses

The monthly biomass of live shoots, dead shoots, litter and below-ground components (g·m⁻²) were compared using Analysis of Variance (ANOVA). Monthly live shoot biomass (g·m⁻²) was subjected to linear regression analysis in order to establish a relation between live shoot biomass (g·m⁻²; dependent variable, *Y*) and monthly rainfall (mm; independent variable, *X*). The linear regression equation used was *Y* = *a* + *bX*, where *a* is the *Y*-intercept and *b* is the slope of regression coefficient (*r*) (Snedecor and Cochran 1967).

Results

During the rainy and summer seasons, *Cymbopogon distans* (grass) was the dominant species with maximum density and IVI. However, during winter season, *Carex cruciata* dominated the site (Table 1). The total density (individual·m⁻²) was maximum (1 206) in September and minimum (4) in December (Table 1).

Biomass and production

The monthly biomass of live shoots, dead shoots, litter and below-ground components was shown in Fig. 1. Analysis of variance (ANOVA) indicated significant differences in biomass of

live shoots, dead shoots, litter and below-ground components in different months ($p < 0.01$ in all the cases).

Table 1. Composition of herbaceous vegetation in the rainy season, winter season and summer season as analyzed in September, December and April, respectively

Growth forms/ Species	Rainy season (September)		Winter season (December)		Summer season (April)	
	Density (m^{-2})	IVI*	Density (m^{-2})	IVI*	Density (m^{-2})	IVI*
Tall forbs						
<i>Bidense biternata</i> (Lour.) Merr & Sherff	1.2	1.87	-	-	-	-
<i>Cranotome furcata</i> (Link.) O. Kuntze	1.6	5.58	-	-	-	-
<i>Gnaphalium hypoleucum</i> DC.	4.4	5.75	1.6	27.0	-	-
<i>Scutellaria angulosa</i> Benth.	6.0	8.09	1.6	46.4	3.6	32.5
<i>Siegesbekia chinensis</i> Linn.	1.2	0.98	-	-	-	-
Short forbs						
<i>Cyanotis vega</i> (Lour.) Schult.f.	7.6	6.49	-	-	-	-
<i>Dicliptera roxburghiana</i> Nees.	4.0	6.21	1.6	60.9	3.2	20.5
<i>Galium aparine</i> Linn.	4.8	4.86	2.0	63.7	5.2	25.1
<i>Micromeria biflora</i> (Buch.- Ham. ex D. Don) Benth.	6.4	8.90	1.0	39.2	7.2	24.6
<i>Nepeta leucophylla</i> Benth.	3.2	4.73	-	-	-	-
<i>Pedicularis pectinata</i> Wall. ex Benth.	5.2	6.54	-	-	-	-
<i>Polygonum nepalense</i> (Meissn.) Hook.f.	6.8	8.06	-	-	-	-
<i>Rumex hastatus</i> D. Don	3.2	7.49	-	-	6.0	27.1
<i>Teucrium royleanum</i> Wall. ex Benth.	3.6	4.41	-	-	-	-
Cushion and spreading forbs						
<i>Cnicus argyranthus</i> (DC) Hook.	3.6	4.03	-	-	0.8	3.8
<i>Oxalis corniculata</i> Linn.	2.8	3.70	-	-	-	-
<i>Parietaria debilis</i> Forst.f.	6.0	14.44	-	-	-	-
<i>Polygonum capitatum</i> Buch.- Ham. ex D. Don	0.8	1.56	-	-	-	-
<i>Trollis japonica</i> (Houtl) DC	2.0	3.34	-	-	-	-
Grasses						
<i>Apluda mutica</i> Linn.	1.6	1.86	-	-	-	-
<i>Arthraxon lanceolatus</i> (Roxb.) Hochst.	10.8	5.44	-	-	-	-
<i>Arundinella nepalensis</i> Trin.	312.0	31.81	-	-	-	-
<i>Carex cruciata</i> Wahlenb.	10.0	5.70	4.0	62.7	6.8	22.0
<i>Chrysopogon serrulatus</i> Trin.	242.0	40.34	-	-	16.0	55.4
<i>Cymbopogon distans</i> (Nees) Wats.	580.0	84.33	-	-	43.6	89.0
<i>Cynodon dactylon</i> (Linn.) Pers.	16.0	9.31	-	-	-	-
<i>Cyperus compressus</i> Linn.	2.4	2.75	-	-	-	-
<i>Dicanthium annulatum</i> (Forssk) Stapt.	15.6	4.85	-	-	-	-
<i>Fimbristylis dichotoma</i> (Linn.) Vahl.	8.0	1.86	-	-	-	-
<i>Imperata cylindrical</i> (Linn.) P. Beauv.	10.0	1.72	-	-	-	-
<i>Setaria glauca</i> P. Beauv.	2.0	2.63	-	-	-	-
Total	1206.4		4.0		67.2	

*Importance Value Index

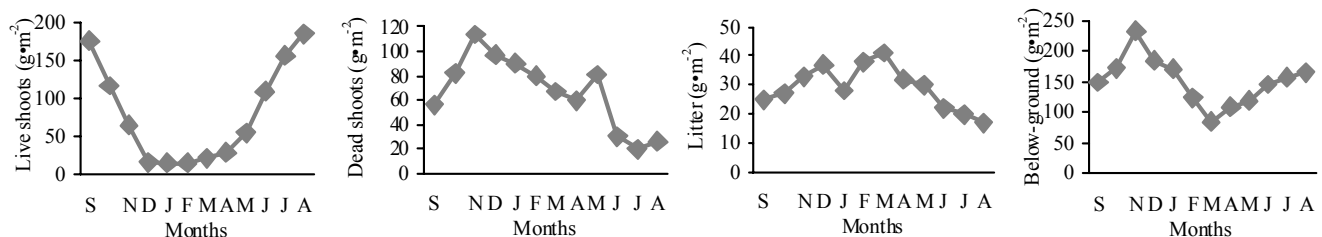


Fig. 1 Monthly biomass (g m^{-2}) of different above- and below-ground compartments

Live shoots

The biomass of live shoots ranged from 15 to 185 g m^{-2} in different months. The live shoot biomass decreased from September to

January (minimum) hereafter it increased gradually during the summer season and then rapidly with the commencement of rainy season. The amount of live shoots biomass is positively related to monthly rainfall as follows:

$$Y_1 = 27.78 + 0.204 X_1 \quad (r = 0.778, p < 0.05)$$

where Y_1 is live shoot biomass ($\text{g}\cdot\text{m}^{-2}$) and X_1 is monthly rainfall (mm).

Live shoot biomass of different growth forms as per cent of community biomass indicated that grasses contributed maximum during rainy and summer seasons while during winter season maximum contribution was from short forbs (Table 2).

Table 2. Live shoot biomass of different growth forms as per cent of community biomass, number of species and species diversity in rainy season, winter season, and summer season as measured in September, December and April, respectively.

Seasons	Growth forms/species richness/ diversity					
	Tall forbs	Short forbs	Cushion and spreading forbs	Grasses	Species richness	Species diversity
Rainy season (September)	8	17	9	66	31	3.56
Winter season (December)	20	68	-	12	9	2.11
Summer season (April)	18	19	<1	63	10	2.50

Dead shoots

The dead shoots biomass ranged from 20 to $114 \text{ g}\cdot\text{m}^{-2}$. The dead shoots biomass increased from September to attain peak in November, thereafter it declined continuously in subsequent months. ANOVA indicated significant differences in dead shoots biomass in different months ($p < 0.01$).

Litter mass

The litter mass ranged from 17 to $41 \text{ g}\cdot\text{m}^{-2}$. The litter mass increased continuously from September to next March, where after it declined in subsequent months. ANOVA indicated significant differences in litter mass in different months ($p < 0.01$). The above-ground biomass structure continuously changes with the change in season. During winter and early summer seasons, biomass production was primarily of dead tissues and of entirely live green tissues during rainy season from June to September.

Below ground biomass

The below-ground biomass ranged from 84 to $233 \text{ g}\cdot\text{m}^{-2}$. The minimum value was found in March and the maximum in November. The below-ground biomass increased from September to November, where after it decreased until March, and increased again in subsequent months. ANOVA indicated significant differences in below-ground component in different months ($p < 0.01$).

Net production

The above-ground net primary production was $171 \text{ g}\cdot\text{m}^{-2}$, below ground net production was $165 \text{ g}\cdot\text{m}^{-2}$ and total net primary production was $336 \text{ g}\cdot\text{m}^{-2}$ (Table 3).

The ratio of above ground biomass to below ground biomass was calculated for month based on total standing crop (live + dead shoots) and below ground biomass. These values ranged between 0.66 and 1.64. It increased from September to December, where after it decreased steadily particularly from January to August.

Table 3. Seasonal above-ground net production, below-ground net production and total net production. All the values are in $\text{g}\cdot\text{m}^{-2}$ and the values in parentheses are per cent of total annual

Seasons	Above-ground production	Below-ground production	Total net production
Rainy season (June- September)	131 (77)	47 (28)	178 (53)
Winter season (October-February)	1 (<1)	84(51)	85 (25)
Summer season (March-May)	39(23)	34 (21)	73 (22)
Annual	171	165	336

Discussion

In most of the herbs, growth began in June with the advent of monsoon rains. Though individual species varied in growth phenologies, their cumulative effects resulted in an increase in community biomass from January to September. That explains why most of increment in biomass occurred during rainy season, when soil was consistently moist and temperature was optimal (the mean monthly temperature being $17\text{--}21^\circ\text{C}$). In the post monsoon period decline in temperature and moisture brought about cessation in new growth and a gradual decline in live shoot biomass.

The understory community is a major component for any forest ecosystem (Hussain et al 2008; Suchar and Crookston 2010). It is critical to many system ecological processes, by providing habitat to many organisms, altering the nutrient cycles, protecting against erosion, and contributing to the communities' diversity (Muir et al. 2002; Kerns and Ohmann 2004) and are considered as good ecological indicators of forest health (Tremblay and Larocque 2001). The botanical composition of the community biomass changed as the growing season advanced (Table 1). The number of species and plant diversity declined from maximum in September to minimum in December (Table 2). Most of the species commence and complete their growth cycle during the rainy season.

The peak growth rate of net accumulation in live shoot biomass is an index of net photosynthetic efficiency of vegetation

under given environmental condition; it also indicates when optimum growing conditions occur at various sites (Sims and Singh 1978a). In tropical grasslands of India the peak growth rate may be as high as $14\text{--}15\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ occurring towards the end of the monsoon season in September (Singh and Yadava 1974; Gupta and Singh 1982b). The peak growth rate of live shoot biomass ($1.8\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) in the present study is within the range (1.2 to $6.5\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) given by Sims and Singh (1978a) for various temperate grasslands of Western North America.

The accumulation of biomass in below-ground parts showed a bi-model pattern of growth; the first peak occurred in August (peak monsoon season) and second peak in November (post monsoon period). Such bi-model patterns of below-ground biomass have also been reported by Singh and Krishnamurthy (1981) and Sah and Ram (1989) from different temperate grasslands of India.

The turnover of below ground biomass in the present site is rather rapid as much as 71% of the below-ground biomass being replaced each year.

The estimated values of aboveground production in the present study ($235\text{ g}\cdot\text{m}^{-2}$) is within the range ($32.6\text{--}333\text{ g}\cdot\text{m}^{-2}$) given by Polakowski and Endles (1985) for herb layer production in certain forest and shrub communities, $1.6\text{--}216\text{ g}\cdot\text{m}^{-2}$ (Ford and Neubound 1971) and $97\text{--}175\text{ g}\cdot\text{m}^{-2}$ (Bazzaz and Bliss 1971) for herb layer production under different forests. The total net production ($336\text{ g}\cdot\text{m}^{-2}$) in the present study was higher than the range of $233\text{--}277\text{ g}\cdot\text{m}^{-2}$ for oak dominated forests of this region (Rana 1987; Kharkwal et al. 2010).

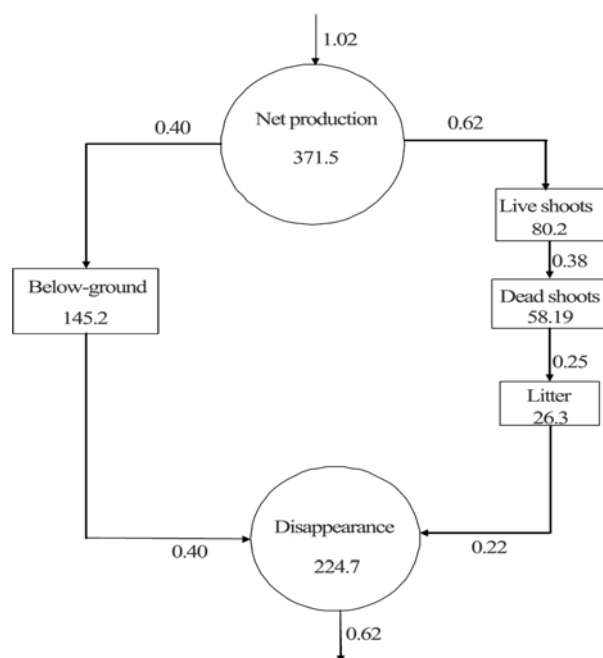


Fig. 2 Net dry matter flow through different compartments. Values in circles are total net primary production and disappearance; values on the arrows are net flux rates in $\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$

The net accumulation and disappearance of dry matter in the present study are shown in Fig. 2. The season-long mean biomass values of live shoots, dead shoots, litter and below-ground

parts are given in boxes. The net flux rates are indicated on arrows. Of the total input of $1.02\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ into the system, about 61% was channeled to above-ground parts and 39% to the below-ground parts. Transfer of live shoots to dead shoots compartments and that of dead shoots to litter compartments was 61% and 65%, respectively. The rate of litter disappearance was $0.22\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ (i.e., 88% of the litter input) and that of below ground was $0.39\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ (97% of BNP). The sum of three values, which represent the total output, was $0.61\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$, which was 61% of the input (TNP). Thus, the present herb layer shows a net accumulation of organic matter indicating seral nature of the community.

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